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LUMINARY Memo #198

TO: Distribution
FROM: Craig Work, Peter Weissman
DATE: 29 January 1971
SUBJECT: DAP performance in Apollo 14 Level 6 tests.
References: LUMINARY Memos 180, 186.

DAP performance in all the powered flight Level 6 tests was found to be normal and satisfactory. Particular attention was given to the special tests 6.5.2 (APS TPI burn) and 6.5.3 (Docked DPS burns). The guidance is inactive during the APS TPI burn (it is an impulse burn of 3.5 seconds) so that performance peculiarities may be traced to DAP operation and performance variation with changing test parameters reflects DAP sensitivity to the changing parameters. The docked burns include both the CM-docked case and the CSM-docked case.

6.2.1 DPS abort from descent at 33000 ft.

This abort maneuver was smooth. During the ascent, slosh build-up was observable in the vehicle rates. When the slosh moved the vehicle state out of the coast zone, a 1.5 jet-sec. burst of RCS firings removed energy from the slosh mode, and the slosh diminished from that point on. A 40° yaw was requested and performed shortly after the abort, with no unusual behavior of the LM.

6.2.2 DPS abort from descent at 7000 ft, Abort Stage at DPS depletion.

The abort occurred about 10 seconds after pitchover, when the thrust level was 5600 lbf. A manual yaw through about -40° followed about 45 seconds later, after a very tight limit cycle had been re-established under GTS control. One minute later, V97 signalled the descent thrust fail, and the abort stage sequence continued the ascent, using the APS. Maximum R axis rate at staging was $8^{\circ}/\text{sec.}$, while the Q axis peak was $3^{\circ}/\text{sec.}$ which was smaller than the Q-axis peaks in the nominal APS limit cycles which followed. During the remaining 5 1/2 minutes

ascent to orbit, there were two periods of P-axis activity, showing double-sided firings and rates up to $3^{\circ}/\text{sec}$.

The Ascent mass value used by the DAP after the sudden shift from descent LM to Ascent LM is HIASCENT. In an actual flight, HIASCENT is pad-loaded, but in our simulations, a Fresh Start value overlays the pad-load. Since the Fresh Start value differs from the Apollo 14 pad-load by only 2%, the DAP performance should not be changed in any significant way by the use of the true value. This comment also applies to the following test.

6.2.3 Abort stage after Touchdown

In the steady state limit cycle, Q-rate peaks decreased from $+5^{\circ}/\text{sec}$ to $+2^{\circ}/\text{sec}$ (at IGNITION + 385 sec.), then increased to $+4^{\circ}/\text{sec}$ (at engine off). The R-axis steady state limit cycle rate peaks decreased from $+3^{\circ}/\text{sec}$ to $+1.5^{\circ}/\text{sec}$ (at IGNITION + 300 sec), then increased to $+4.5^{\circ}/\text{sec}$.

The peak Q-axis attitude error decreased slowly from $+3^{\circ}$ throughout the burn, and the R-axis attitude error remained within $+1.7^{\circ}$ without much variation.

P-axis ascent attitude error hung on one side of the dead band during most of the burn, when the rate was under $0.1^{\circ}/\text{sec}$. Exceptions were seen in yaw during the two periods of P-axis rate activity centering about IGNITION + 140 sec and IGNITION + 300 sec, when yaw rates reached $+3^{\circ}/\text{sec}$.

The initial APS Q-axis limit cycle rates of $+5^{\circ}/\text{sec}$ combined with the $-10^{\circ}/\text{sec}$ rate commanded during the automatic pitch maneuver to yield an estimated peak of $-15^{\circ}/\text{sec}$. The R-axis abort stage rate peak was $7.5^{\circ}/\text{sec}$. Attitude errors at abort stage reached maximum of $+3^{\circ}$ (Q), and $+2.6^{\circ}$ (R).

6.3.2 Ascent from Lunar Surface

Five seconds after IGNITION and staging, a large yaw is requested, and fifteen seconds later the transients are damped. Meanwhile, the normal pitchover after the vertical rise phase was initiated about 9 seconds after IGNITION. A pitch rate peak of $-17^{\circ}/\text{sec}$ occurred as normal limit cycling combined with the guided maneuver. Post-burn P-axis limit cycles had a 25 sec period with 0.3° deadband and a 75 sec. period with a 1° deadband.

6.4.1 Nominal Automatic Lunar Landing.

Ignition transients were small, and pitch and roll control was maintained by the trim gimbal alone for about 400 sec. after the throttle-up transient was damped. P-axis rates were uniformly below $\pm 0.1^{\circ}/\text{sec}$ rising to transient values of $-0.2^{\circ}/\text{sec}$ at automatic windows-up (30,000 ft. altitude) and reaching $0.5^{\circ}/\text{sec}$ at P66 maneuver to local vertical for straight descent.

Q-axis rates were generally below $0.5^{\circ}/\text{sec}$ until slosh activity became noticeable (TIG + 400). Rates during the slosh period were $\pm 1.5^{\circ}/\text{sec}$. continuing to touch-down, with transients at P64 and P66. Pitchdown transient at P64 is performed at $-10^{\circ}/\text{sec}$., and reduction of forward velocity at P66 entry generates rates of $\pm 4^{\circ}/\text{sec}$.

R-axis rates resembled Q-axis rates, but the P64 transient was $\pm 2^{\circ}/\text{sec}$ and the P66 transient was no larger than the slosh oscillations. P-axis maximum attitude error was -1.8° with extremely small rates; otherwise, the error was less than 1° . During slosh period, yaw error went to 0.8° in spite of a 0.3° deadband. Q-axis attitude errors were under $\pm 0.5^{\circ}$ before the slosh period, under $\pm 1.5^{\circ}$ until P64. Pitchover transient showed -7° error, then pitch errors stayed within $\pm 0.5^{\circ}$ until 15 sec before touch-down, when they rose to $\pm 1.0^{\circ}$.

R-axis attitude errors were within $\pm 0.5^{\circ}$ before the slosh period, within 1.5° during the slosh. P64 transient is about 1.5° , errors remain under $\pm 1.0^{\circ}$ until touch-down.

6.4.2.1 Landing with N69 redesignation and with ROD activity,
and manual throttle. (N69 10K/5K ft.)

The redesignation produced the R-axis maximum rate of $1.8^{\circ}/\text{sec}$. The R-axis maximum attitude error (1.4°) occurred then, also, and was repeated during the period of maximum slosh activity, 400-650 sec. after IGNITION. The P64 pitchover produced the Q-axis max rate of $10^{\circ}/\text{sec}$. The DAP showed a good response to the flurry of guidance adjustments which accompanied the return to MODE SELECT AUTO, after the ROD and throttle exercise in ATT HOLD. During this adjustment period, the Q-axis rate reached $10^{\circ}/\text{sec}$ and the Q error reached 7° .

6.4.2.2 Landing with two redesignations; first, N69, then with the ACA.
ROD in AUTO and in ATT HOLD.

The first redesignation yielded very little P-axis disturbance, but the second (ACA) required a $-5^{\circ}/\text{sec}$ yaw rate and showed a 3.5° yaw attitude error.

Q-axis response to the N 69 redesignation was mild, but rates of $-11^{\circ}/\text{sec}$ showed at P64 pitchover and at return to AUTO after initial ROD activity. The ACA redesignation produced pitch rates of $2^{\circ}/\text{sec}$. Q-axis attitude errors reached -10° and $+6^{\circ}$ at P64 and at the return to AUTO after ROD, respectively.

6.4.2.3 Landing with ACA redesignation, ROD activity.

P-axis maximum rate of $5^{\circ}/\text{sec}$ and attitude error of -1.5° occurred at redesignation. Q-axis maximum rate occurred at P64 pitchover and at redesignation, $-10.8^{\circ}/\text{sec}$. The maximum attitude error about the Q-axis was -7° , also at redesignation. The R-axis maxima in rate and in attitude error were $+10^{\circ}/\text{sec}$ and -6.5° , both occurring when the MODE SELECT switch went from ATT HOLD to AUTO after ROD activity.

6.5.1 LM De-orbit test for Apollo 14

See LUMINARY Memo #180, "Apollo 14 LM De-Orbit Test" for a detailed discussion of this P99 burn.

6.5.2 APS Impulse Burn

A matrix of tests was run for this burn, exploring the results of off-nominal conditions. Performance of the DAP was satisfactory. A paraphrase of the detailed DAP performance report was included in LUMINARY Memo # 186, "APS Impulse Burn for Apollo 14".

6.5.3.1 Docked DPS P40 Burn, CSM/LM6.5.3.2 Docked DPS P40 Burn, CM/LM

The matrix of tests covering these burns is described and summarized on the following pages.

<u>Test Matrix</u>		LM Loading		
CSM Loading		100% DPS	65% DPS	30%DPS
	75% SPS	Short	Short	Short
	25% SPS	Long	Short	Short
	CM alone	Long	Short	Short

"Long" runs go almost to DPS depletion, ≈ 600 sec.

"Short" runs show the first 60 sec of a longer burn.

1. A 3σ GTS mistrim is about 0.5° .
2. No bending model was employed in the CM-alone runs because none is available.
3. A non-linear slosh model was included in all runs.
4. The thrust profile was 5 sec at 10%, 21 sec at 40%, and FTP thereafter.
5. The LGC was loaded with the actual LM and CSM (or CM) mass values in all runs.

ID	IGNITION TRANSIENT RESPONSES								
	Mistrim at 40% Thrust, Degrees		Max. Att. Errors, Degrees			Max Rates, Deg/sec			Steady State Characteristics
	Q	R	P	Q	R	P	Q	R	
<u>6.2.3.1</u>									Burn time: 500 sec
25% SPS	-.02	-1.20	.32	3.4	6.9	.00	.43	.52	0.8 lb RCS used
100% DPS	-.02	-1.20							during burn excluding ullage. Ignition transient damped in 40 sec. At cut-off rate oscillations of 1.45°/sec about R. Slosh build up 350 sec. after ignition with +0.1°, about both axes, gets to ± .32 at end.
									N85 (1.3, 0, 0)
25% SPS 65% DPS	-.13	-1.16	.81	1.1	7.7	.00	-.20	-.78	Damped in 45 sec
25% SPS 30% DPS	-.12	-1.15	.92	1.8	10.5	.00	-.36	-1.0	Damped in 45 sec.

ID	IGNITION TRANSIENT RESPONSES									Steady State Characteristics
	Mistram at 40% Thrust, Degrees		Max. Att. Errors Degrees			Max. Rates, Deg/sec				
	Q	R	P	Q	R	P	Q	R		
75% SPS 00% DPS	+.39	-1.32 ⁰	-.95	2.7	7.6	.16	-.50	-.83	Damped in 40 sec.	
75% SPS 65% DPS	.40	-1.29	.75	2.8	9.8	-.025	+.52	-.95	Damped in 50 sec.	
75% SPS 30% DPS	.40 ⁰	-1.29 ⁰	-.82	1.8	12	-.04	+.47	-1.2	Damped in 40 sec.	
6.2.3.2 CM-alone 100% DPS	-.14	-1.03	-.7	3.4	7.0	0	<u>+.5</u>	-.7	Burn time: 549 sec. P-axis: limit cycle period gradually decreases from 10 to 3 sec. Q-axis: limit cycle with 2.5 sec period - apparently slosh-related suddenly increases about 360 sec. after ignition to less than 0.5 ⁰ peak-to-peak R-axis: similar to Q but somewhat smaller. At cut-off rates of +.35 /sec about both axes. 19.5 lb RCS used during burn excluding ullage. N85 (+1.5, +.2, 0).	
CM-alone 65% DPS	-.12	-1.03	-.7	<u>+1.3</u>	5.5	.03	-.45	-.75	Transients damped in about 40 sec.	
CM-alone 30% DPS	-.12	-1.00	-.7	1.2	9.0	.03	-.48	-1.0	Transients damped in about 40 sec.	